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Overwintering, Spring Emergence and Host Synchronization of Two Egg Parasites of the Beet Leafhopper in Southern Idaho

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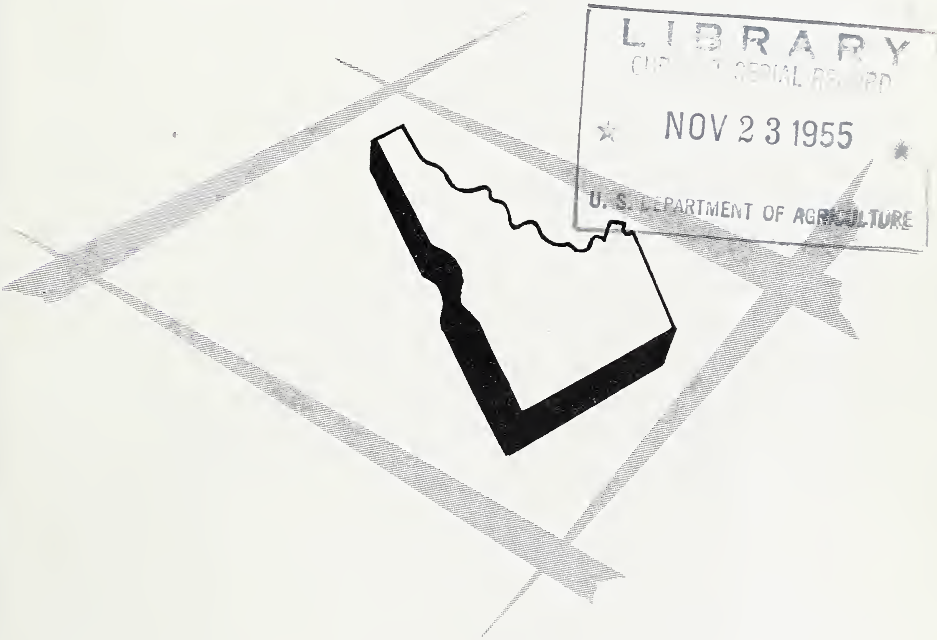

Circular No. 967

U. S. DEPARTMENT OF AGRICULTURE

Contents

Page
Estimation of parasite populations 1
Overwintering of the parasites 2
The diapause 4
    Effect of temperature on diapause 4
    Time diapause is broken 4
    Time of entering diapause 8
    Factors influencing the breaking of diapause 9
Determination of the time of spring emergence 10
Sex ratio of parasites 13
Synchronization of parasite and host 14
Summary 15
Literature cited 16

THE BEET LEAFHOPPER is a serious menace to sugar beet, tomato, and other crops in the West because it is the only known carrier of curly top disease, which it transmits to these and many other plants. Since 1950, when it was proved that this insect is not native to North America, there has been renewed interest in the possibility of utilizing natural enemies for its control.

Washington, D. C. Issued October 1955

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Overwintering, Spring Emergence and Host Synchronization of Two Egg Parasites of the Beet Leafhopper in Southern Idaho[1]

By Chas. F. Henderson, *entomologist, Entomology Research Branch, Agricultural Research Service*[2]

The most abundant egg parasites of the beet leafhopper (*Circulifer tenellus* (Baker)) reared in southern Idaho from 1932 to 1937 were two species of Trichogrammatidae,[3] *Aphelinoidea plutella* Gir. and *Abbella subflava* Gir. They were present in practically every environment where breeding of the leafhopper occurred. The highest populations developed in the summer breeding areas where Russian-thistle (*Salsola kali* var. *tenuifolia* Tausch) was the principal host, although fair numbers were also found in the overwintering and spring breeding areas on annuals such as tansymustard (*Descurainia pinnata* var. *filipes* (A. Gray) Peck), and in the cultivated areas on the sugar beet (*Beta vulgaris* L.)

Since these parasites commonly overwinter within leafhopper eggs deposited in Russian-thistle, this widely distributed host plant was selected for studies on the overwintering and spring emergence of the two parasites. Both species spend the winter as pupae within darkened egg shells under the dry epidermis of the host plant. They remain in this stage until spring temperatures cause them to emerge as adults. The emergence from the overwintering host usually begins in the latter part of April and continues throughout most of May. This circular reports studies on the time and duration of this emergence period, and its synchronization with oviposition of the overwintering brood of the beet leafhopper in the spring. These studies were conducted in southwestern Idaho from 1932 to 1937, with headquarters at Twin Falls.

Estimation of Parasite Populations

For a study of fluctuations in populations of egg parasites, host-plant samples were collected in the field and the contained insects were reared in especially constructed cabinets as described by Henderson (*5*).[4] This was necessary because of the extreme difficulty of detecting parasitized and unparasitized leafhopper eggs in the field, and the apparent impossibility of making specific identifications of these insects in the immature stages. The rearing cabinets, held at a constant condition of light, temperature of 80° F., and relative humidity of 35 to 50 percent, were used for the determination of parasite populations in a given unit of host-plant material. The number of insects reared did not express the absolute populations present, since all the parasites within the samples did not reach maturity, and only a certain percentage of them were attracted to the collecting end of the rearing cages. However, since such estimates were made under comparable conditions, they could be used for measuring fluctuations in field populations that would be indicative of successive broods, winter mortalities, spring emergence, and many other phenomena under study.

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[1] Submitted for publication March 22, 1955.

[2] In cooperation with the Idaho Agricultural Experiment Station.

[3] Determinations were made by A. B. Gahan, of the former Bureau of Entomology and Plant Quarantine.

[4] Italic numbers in parentheses refer to Literature Cited, p. 16.

Overwintering of the Parasites

For a determination of the effect of winter mortality on populations of the two species of parasites, large quantities of dry Russian-thistle containing parasitized leafhopper eggs were collected in the fall and held out of doors during the winter. The plants were placed in a single layer on the ground and covered with a 2-inch-mesh wire screen to keep them from blowing. It is believed that the screen had no appreciable effect on the temperatures and humidities to which the parasites were exposed. The effect of overwintering on parasite populations was to be determined by comparing the number of insects reared per unit of host plant in the fall with that from similar rearings made the following spring.

For a determination of the density of fall populations, an 80-gram sample of dry Russian-thistle from under the screens was placed in each of 15 rearing cages on September 4, 1932, and held there until all emergence had ceased. Emergence began during the first 24 hours, an indication that some of the insects were present as unemerged adults. On an average 9 *plutella* emerged per sample in this lot. A larger collection of Russian-thistle from under the screens was placed in the cabinets on October 3, but no parasites emerged although it was held in the cabinets for 3 weeks. An examination of the host-plant material revealed a number of darkened, parasitized eggs, and it appeared that the parasites in the second collection were in diapause. To determine whether these parasites would emerge the following spring, the rearing cages containing the Russian-thistle were stored out of doors during the winter in a shaded position on the north side of the greenhouse. On March 31, 1933, before the temperatures were appreciably above 50° F. in the field, these caged host plants were again placed in the incubation cabinets. On an average 39 *plutella* and 3 *subflava* emerged per sample of this material, an indication that the insects had been in diapause in October.

Emergence curves of *plutella* from the material held over winter and from two samples of Russian-thistle not subjected to higher-than-normal temperatures in the fall are shown in figure 1. The first of the

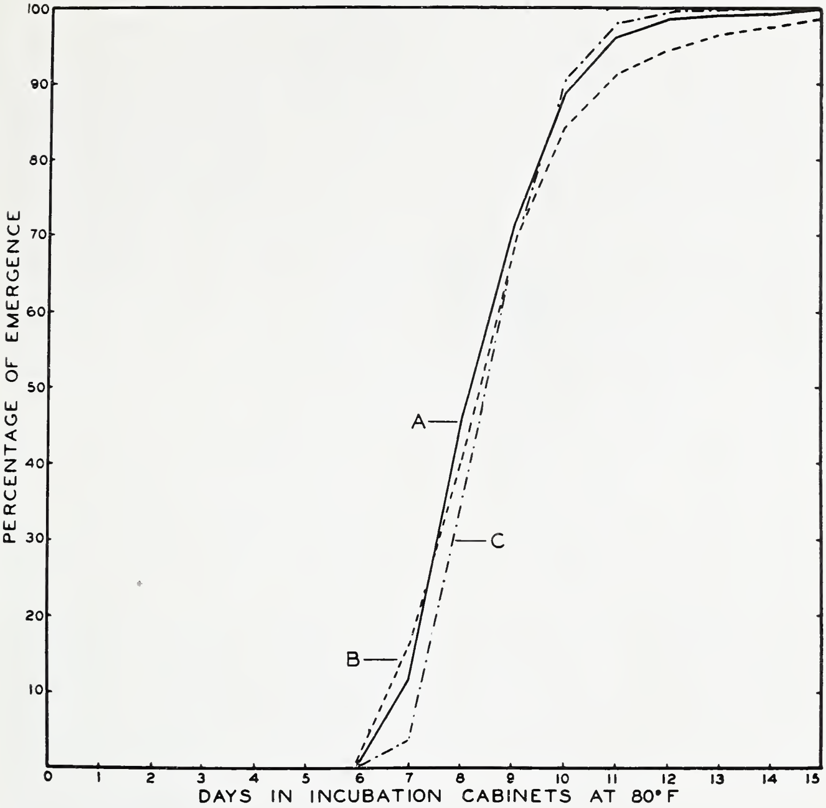

FIGURE 1.—Emergence of *Aphelinoidea plutella* from beet leafhopper eggs in dry Russian-thistle: *A*, Material placed in the cabinets on March 31, 1933, from which no emergence had occurred when held in the cabinets at 80° F. from October 3 to 24, 1932; *B*, material collected in the field and placed in cabinets on November 30, 1932; *C*, material collected in the field and placed in cabinets on March 8, 1933.

two samples was collected in the field and placed in the cabinets on November 30, 1932; the second sample was held out of doors the entire winter and placed in the cabinets on March 8, 1933. The emergence curves for the three lots of samples were not appreciably different; apparently the parasites had developed little during the winter. In each sample the first emergence began after 6 days and the mean occurred at about 8 days. Because of the small number of *subflava* in these samples, satisfactory emergence curves of this species were not available. However, *subflava* also showed no indication of development during the winter. For each collection date, emergence began after 7 days and the mean occurred at nearly 9 days.

The Diapause

Effect of Temperature on Diapause

In the previous test a constant temperature of 80° F. maintained for approximately 3 weeks in the fall did not reduce the time required for *plutella* to emerge in the spring. In another test 4 lots of beet leaves containing parasites that appeared to be in diapause were held from November 4 to 12, 1932, in constant-temperature cabinets maintained at 65°, 70°, 80°, and 90° F. On January 30, 1933, after having been out of doors most of the winter, these leaves were placed in the incubation cabinets and the emergence of *plutella* was compared with that from another lot not subjected to abnormal temperatures in the fall. There was no appreciable difference between any of the emergence curves regardless of the temperatures to which the insects had been subjected. The greatest number emerged from the leaves held at 70°, and the smallest from those held at 90°. Although the higher temperatures may have had some lethal effect on the parasites, no appreciable influence on the time of spring emergence could be attributed to the temperature to which they had been exposed during the previous fall.

The diapause apparently affected both species of parasites at the time they entered pupation, since examination of a number of insects that had failed to emerge in the fall indicated that they were alive and in the early pupal stage. Another large series of unemerged parasites examined in March demonstrated that no visible changes had taken place during the winter. If the rest period began at a definite stage in the development of the parasite, a fairly constant accumulation of developmental temperature would be required before the adults could emerge the following spring. To determine whether such was the case, spring emergence curves obtained over a period of 5 years were compared. Each year samples of dry Russian-thistle were collected between January 10 and March 8, before any temperatures appreciably above 50° F. had been recorded in the nearby Weather Bureau shelter. These samples were held in the incubation cabinets and emergence records were taken daily (fig. 2).

In practically every sample during the 5 years, emergence of these two species began after 6 days in the cabinets. The mean emergence of 56,162 *plutella* occurred after an accumulation of 255 day-degrees above 50° F. in the constant-temperature cabinets. The mean emergence of 16,509 *subflava* during the same period occurred after 265 day-degrees. The similarity of the emergence curves for the different years indicates that the parasites were in almost the same developmental stage during the winter, and that approximately the same temperature increment was required before emergence began in the spring.

Time Diapause is Broken

In the fall of 1933 a test was conducted to determine the approximate time at which the diapause was broken. Two almost identical lots of beet petioles infested with leafhopper eggs parasitized by *plutella* and *subflava* were collected. One lot was placed on the soil surface, and the other on a wire screen suspended 6 inches above the

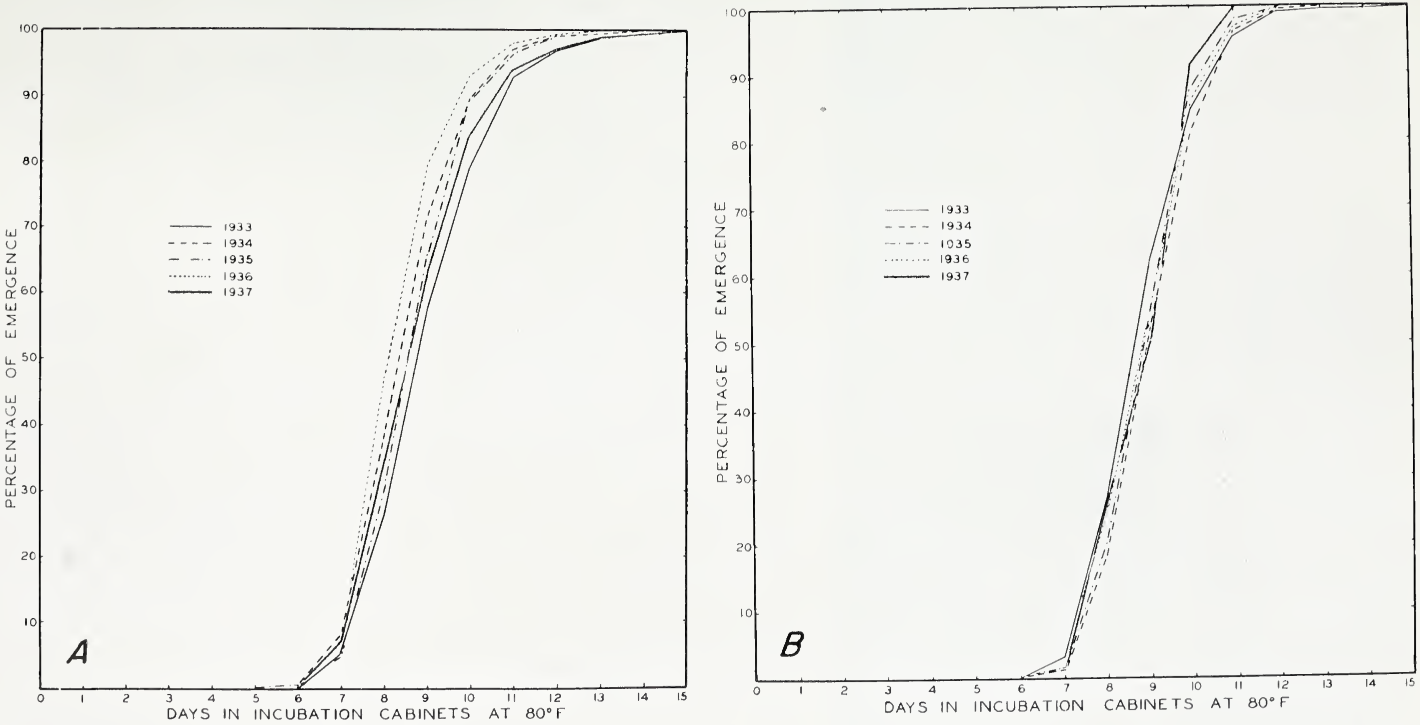

Figure 2.—Daily emergence of parasites of beet leafhopper eggs in dry Russian-thistle held in incubation cabinets at a constant temperature of 80° F. during the springs of 1933 through 1937: *A*, *Aphelinoidea plutella*; *B*, *Abbella subflava*.

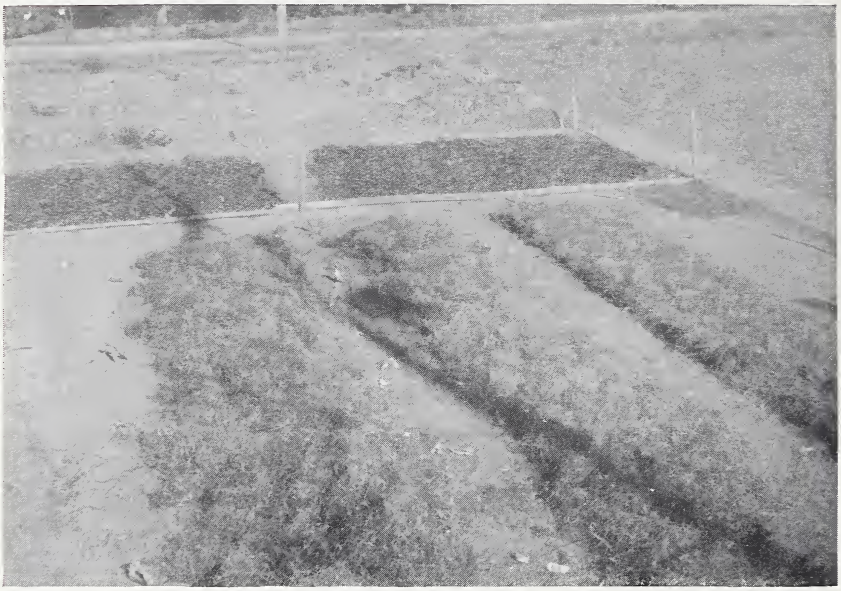

Figure 3.—Area in which Russian-thistle plants and beet leaves infested with parasitized leafhopper eggs were stored during the winter. Twin Falls, Idaho.

surface (fig. 3), which would simulate the environment of the leafhoppers in Russian-thistle. At frequent intervals lots of 100 petioles were taken at random from the wire screen and placed in the incubation cabinets (table 1).

There was not only a gradual increase in the number of *plutella* emerging from each sample as the season progressed, but also a shortening of the period during which they emerged. On the assumption that the insects were in diapause at the beginning of the test, the increasing number of parasites reared from each successive sample was undoubtedly due to the gradual breaking of this rest period. The shortening of the time during which they emerged in the cabinets was probably due to a combination of factors. From table 1 it appears that, after reaching the stage at which diapause began, the minimum time necessary for the parasites to emerge at 80° F. was 6–7 days and the maximum about 12 days. At the beginning of the test many of the *plutella* were undoubtedly in the larval stage and required more than 12 days for emergence. Developmental temperatures received by these larvae in the field should reduce the time necessary for them to reach the pupal stage in the incubation cabinets. After reaching this stage diapause probably began, and any further accumulation of favorable temperature would have had no appreciable influence on the time required for them to emerge.

The few parasites requiring less than 6 days for emergence were probably the more advanced pupae (or unemerged adults) that were not subject to the limitations of the rest period. They would continue to develop and either emerge in the field as adults or be killed by the unfavorable temperatures prevailing at that season of the

TABLE 1.—*Emergence of* Aphelinoidea plutella *from beet leafhopper eggs in beet petioles placed at intervals in incubation cabinets held at a constant temperature of 80° F. 1933*

Date collected	Number of parasites emerging on indicated day																			Percent emerging from 7th to 12th day
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18[1]	Total	
Oct. 19			1	0	1														2	0
24		3	0	0	0	0	0	0	0	1	0	0	0	0	0	2	1		7	14
31		1	0	1	0	0	1	0	1	0	0	0	0	1	1	1			7	29
Nov. 4			1	0	0	0	0	2	2	4	0	0	1	0	0	0	0	1	11	73
7				1	0	0	0	0	2	1	3	3	1						11	82
10	1	0	0	0	0	0	1	2	1	2	1	1	1	3	0	2	2	2	19	42
13								4	1	0	0	0	0	3	1	1	0	1	11	45
16					1	0	1	4	5	1	1	1	2	0	0	1	0	1	18	72
19				1	0	0	0	2	3	2	0	4	2	1	0	0	1		16	69
23						1	0	0	7	4	0	3	2	0	1	2			20	70
27								5	4	5	1	2	0	3	1	1	1		23	74
Dec. 1						1	0	9	4	5	3	1	1	3	2	1	1		31	71
4						1	4	18	17	4	3	1	1	2	1	0	2		54	87
6							8	23	7	7	4	2	1	0	0	1			53	96
9						1	7	17	12	4	3	2	1	0	2	0	1	1	51	88
12							12	28	13	5	1	0	0	1	0	0	1		61	97
15							9	20	26	6	3	2	3	2	1				72	92
18							3	10	16	10	8	4	2	2	0	1			56	91
21						2	12	15	29	12	5	5	0	1					81	96
24							3	25	35	5	3	1	2						74	97
27							5	19	22	7	3	1							57	100
Jan. 1							1	22	32	14	4	7	1	1					82	98
6							11	29	20	6	2	1							69	100

[1] 15 parasites emerged after the 18th day.

year. The elimination of all parasites in stages not affected by diapause would confine emergence to a period of a few days, covering the normal spread for emergence at a constant temperature of 80° F.

The breaking of the rest period for *subflava* followed the same pattern, although the smaller number of individuals per sample resulted in much more erratic data.

Time of Entering Diapause

Studies were undertaken to determine the time of year that *plutella* and *subflava* entered diapause. Early in April 1935 short sections of growing beet petioles containing eggs of the beet leafhopper were placed in cloth-capped vials, held in the incubation cabinets for 4 days, and then exposed to parasitism by adults that had overwintered as pupae within dry Russian-thistle plants. These studies were conducted in a partially-shaded greenhouse where fluctuating temperatures prevailed. The first-brood adults that emerged each day from the parasitized eggs were recorded, removed, and allowed to parasitize a new lot of eggs. After emergence ceased, the dry beet petioles were held out of doors until the following spring, when emergence records were again taken. This process was repeated for the second, third, and fourth broods of parasites.

All of the first brood of *subflava* emerged the first season (table 2), whereas from 31 to 45 percent of the other broods emerged the following spring. In these tests the leafhopper eggs were not readily parasitized by *plutella*, but the limited data obtained showed that even some of the first brood of this species did not emerge as adults until the following spring.

TABLE 2.—*Emergence of* Abbella subflava *from eggs of the beet leafhopper during the summer of 1935 and the spring of 1936 in the greenhouse at Twin Falls, Idaho*

Brood of *subflava*	Date of parasitization	Percentage of total emergence	
		Summer of 1935	Spring of 1936 (diapause)
1	May 14 to June 16	100	0
2	June 19 to July 13	55. 4	44. 6
3	July 15 to 29	54. 9	45. 1
4	Aug. 7 to 24	69. 1	30. 9

It is apparent that a considerable portion of the second, third, and fourth broods of the parasites entered diapause in the summer of 1935, and remained in diapause until the following spring. While the diapause should be beneficial in maintaining the species over adverse periods, it is believed to limit the building up of large numbers of parasites at a time when they would be of greatest value in reducing host populations. The diapause tends to accumulate parasites in the pupal stage throughout the summer, causing them to emerge over a short period the following spring. This would be a helpful adaptation were it not for the scarcity of adult leafhoppers in the Russian-thistle areas during the spring emergence period of the parasites. Thus the enormous populations of parasites built up at the expense of summer reproductions are largely wasted.

Factors Influencing the Breaking of Diapause

The effect of low temperatures in breaking the rest period of *plutella* during the fall and winter of 1933–34 was indicated by a slight difference in its time of emergence from beet petioles held on the soil surface and at 6 inches above the surface (fig. 4). The lower daily minimum temperatures at the 6-inch level were associated with the somewhat earlier emergence of *plutella*. Although no parasites issued until minimum temperatures of approximately 30° F. had been reached, it is believed that emergence was the result of an accumulation of low temperatures somewhat above this level.

Another test was conducted to determine whether the rest period of the two parasites could be broken by subjecting them to constant low temperatures. On September 20 four lots of beet petioles were taken at random from the outside storage area. Three of them were placed in the local icehouse, where temperatures of 35° to 40° F. were maintained; the fourth lot was held out of doors on wire screens 6

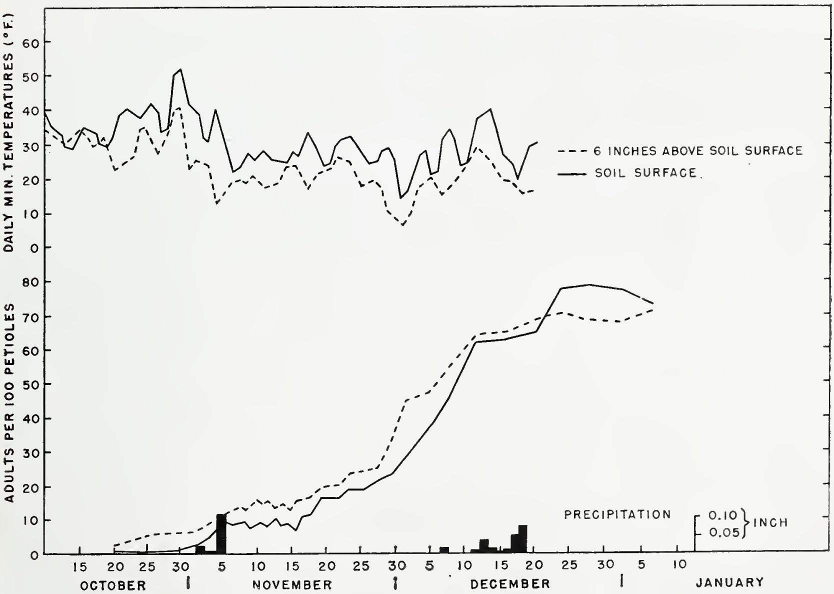

Figure 4.—Rearing of *Aphelinoidea plutella* from beet leafhopper eggs in beet petioles held in the field on the soil surface and 6 inches above the surface, together with temperature and precipitation records in the storage area. Twin Falls, Idaho.

inches above the soil surface. After 7, 15, and 27 days of exposure at the two positions, samples from the four lots were placed in incubation cabinets and held at 80° for parasite emergence. From the material held in the icehouse, 2, 22, and 47 *plutella* and 1, 5, and 8 *subflava* emerged per cage after the three respective exposure periods at low temperature, whereas no parasites emerged from identical samples held in the field during the same time. It is evident that the rest period had been broken by the low temperatures prevailing in the icehouse.

Precipitation records were taken in the outside storage area, and these data are included in figure 4. It is unlikely that moisture was responsible for the termination of the rest period. At the time of the first precipitation recorded after initiation of the test—0.02 inch on November 1—emergence of this species had already begun. During the next 4 days there was a total rainfall of 0.11 inch. Although there was no further precipitation until 0.01 inch fell on December 7, the breaking of the rest period continued at a gradual rate. Between December 12 and 18 there was a total rainfall of 0.21 inch, but by this time the rest period had been almost completely broken.

The artificial breaking of the rest period by subjecting the parasitized eggs to low temperatures in the fall would be useful in determining fall populations for comparison with those in the spring in evaluating the effect of winter conditions on parasite survival. When they are allowed to remain in the field until January, there might be some mortality due to low temperatures; moreover, heavy snow cover often precludes the taking of samples in the field at this time of year.

Determination of the Time of Spring Emergence

In the winter and early spring before the parasites had been subjected to any appreciable amount of developmental temperature, lots of 15 or more 80-gram (average) samples of dry Russian-thistle were taken from under the wire screens and held in the incubation cabinets until all the parasites had emerged. From the total number of parasites emerging, the percentage that emerged on each day was calculated. Over a period of years it had been determined that at 80° F. *plutella* began to emerge on the sixth or seventh day, with 50-percent emergence occurring after 8½ days. A slightly greater temperature accumulation was required for the emergence of *subflava* (fig. 5). The time required for the initial emergence of adult parasites in the incubation cabinets during the spring should be decreased by the amount of developmental temperatures to which the insects in the field were subjected, until emergence would finally begin during the first 24 hours in the cabinets. When this occurred it was assumed that emergence was about to begin in the field. At this time 50 percent of the parasites emerged within approximately 4 days. Since the time required for 50-percent emergence was less dependent on the number of parasites included in the sample than that for initial emergence, the former estimate was believed to be more reliable for determining the development of the parasites in the field. Consequently, when 50 percent of the parasites were found to have emerged on the fourth day in the cabinet, it was assumed that emergence had started in the field.

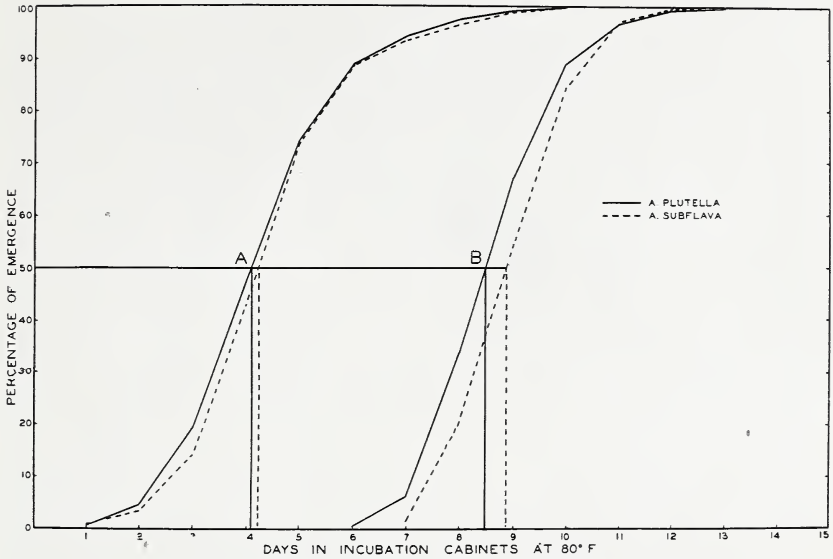

Figure 5.—Average emergence of *Aphelinoidea plutella* and *Abbella subflava* from beet leafhopper eggs in cabinets held at 80° F.: *A*, From dry Russian-thistle collected in the spring when emergence was just beginning in the field; *B*, from material collected during the winter and early spring before the parasites had been subjected to any developmental temperatures.

After the parasites had begun to emerge in the field, host-plant samples were placed in the incubation cabinets at frequent intervals for quantitative rearing of the contained parasites. For this purpose the population present was expressed as the number of insects per 100 grams of dry plant material. The mean emergence of a given parasite from an adequate number of units of host-plant material, as determined from tests made prior to the first emergence date but after completion of diapause, was considered as the preemergence parasite population in the material held under the wire screens for future sampling. The percentage of the total population that emerged on any subsequent date was determined by the decrease from the original population, the reduction being attributed almost entirely to field emergence. In southern Idaho emergence of *plutella* usually began during the latter part of April and continued through most of May. Spring emergence records were taken from 1932 to 1935, as shown in figure 6. In 1932 the records were taken at Hollister, and in 1935 at Berger. During the other 2 years the samples were held at the laboratory grounds in Twin Falls. In the spring of 1934, however, high temperatures occurred much earlier in the season and emergence of the parasites began about 1 month earlier. The spring migration of the beet leafhopper also began about 1 month earlier.

Since a fairly constant accumulation of developmental temperature is apparently required for emergence of the parasites in the spring, the beginning of emergence could be determined with a fair degree of accuracy from the accumulation of such temperatures after diapause

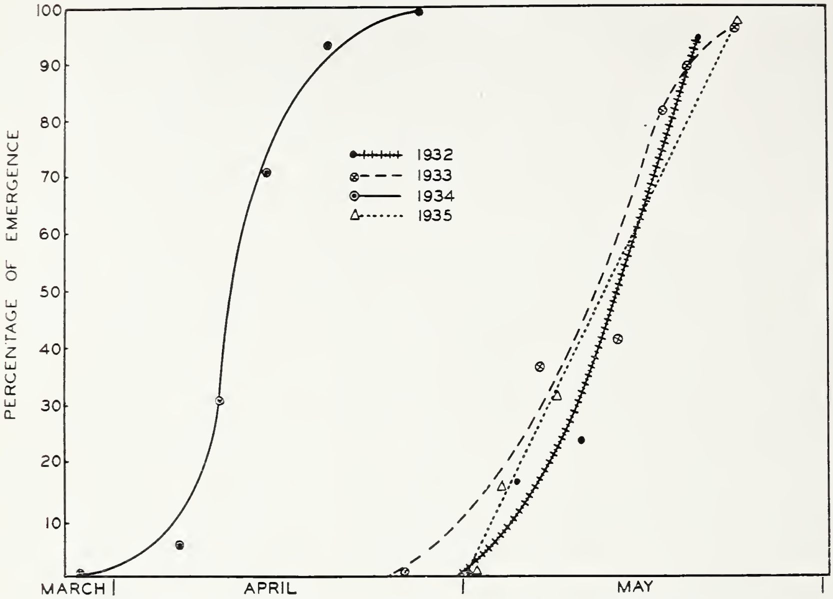

FIGURE 6.—Emergence of *Aphelinoidea plutella* from beet leafhopper eggs in Russian-thistle in southern Idaho during the springs of 1932–35.

ceased. For this purpose March 1 was selected as the starting point, and the temperature accumulations, expressed as day-degrees above 50° F., were determined from thermograph records taken in a nearby standard Weather Bureau shelter. These measurements were made with a polar planimeter. Table 3 presents temperature accumulations for 1933, 1934, and 1936 prior to the first emergence of *plutella* in the spring. The duration of the period was determined by emergence in the incubation cabinets at 80° F. from plant material collected at frequent intervals. Although these day-degree accumulations may be used to compare spring temperatures between years, they do not indicate the total developmental temperature required by the parasites for emergence. Accumulations of unshaded temperatures from 0 to 6 inches above the soil surface, the environment occupied by the parasites within dry Russian-thistle plants, would be much greater than those in a standard Weather Bureau shelter prior to the beginning of spring emergence.

The average date for the first emergence of *plutella* occurred when there had been an accumulation of 144 day-degrees above 50° F. (The average emergence of *subflava* occurred at a slightly later date.) The positive correlation between emergence of parasites and the first discovery of spring-brood beet leafhoppers in the field is of interest. The earliest occurrence of both parasite and host was in 1934, followed by 1936 and 1933. The date at which sufficient temperature accumulations for emergence occurred also followed the same order. The insects appearing in the beet fields were developed in warmer areas, where they matured at an earlier date but where temperatures were apparently correlated with those of the Berger-Twin Falls area.

TABLE 3.—*Emergence of* Aphelinoidea plutella *from eggs of the beet leafhopper in dry Russian-thistle in cabinets in the spring, temperature accumulations to the first emergence date, and first appearance of beet leafhoppers in cultivated fields in 1933, 1934, and 1936*

Year	Duration of emergence in cabinets	Day-degrees above 50° F. to first emergence date	Beet leafhoppers first discovered in beet fields on—
1933	Apr. 25 to May 24	132	June 6
1934	Mar. 27 to Apr. 21	152	Apr. 27
1936	Apr. 17 to Apr. 30	149	May 25
Mean		144	

Sex Ratio of the Parasites

Of 48,429 *plutella* and 11,419 *subflava* reared in the incubation cabinets, 63 and 52 percent, respectively, were females. These sex ratios were based on parasites reared from dry Russian-thistle collected from January to March before there had been any appreciable accumulation of developmental temperature in the field. As only those parasites that had successfully reached the illuminated end of the rearing cage were included, it seemed possible that this factor might have favored the females. The longevity of male insects is usually less than that of females, and thus a smaller percentage of the males might have survived to reach the light. However, since the parasites had to travel a maximum of only 10 inches to reach the illuminated end of the cages, this is very unlikely. It is also possible that a difference in the degree of phototropism was associated with sex, although there was no evidence to support this assumption. If such a difference did occur, it would probably have been accentuated at lower light intensities. The sex ratios of the parasites recovered at light intensities of 66, 110, and 275 watts per cabinet were 70, 69, and 67 percent females, respectively, for *plutella* and 51, 48, and 52 for *subflava*. Apparently within the range of light intensities tested, this factor did not influence the sex ratio of the parasites recovered in the incubation cabinets.

Although slightly more females than males of these two species were produced, the latter predominated during the first and last portions of the emergence period (fig. 7). The effect of temperatures above 80° F. on the sex ratio of *plutella* was also observed.

In rearing individuals of this species from short sections of mustard stems the females observed at the various constant temperatures employed were as follows: 55 percent at 70° F., 57 percent at 80°, 62 percent at 90°, and 87 percent at 100°. Apparently there was a high preemergence mortality of males at 100° F.

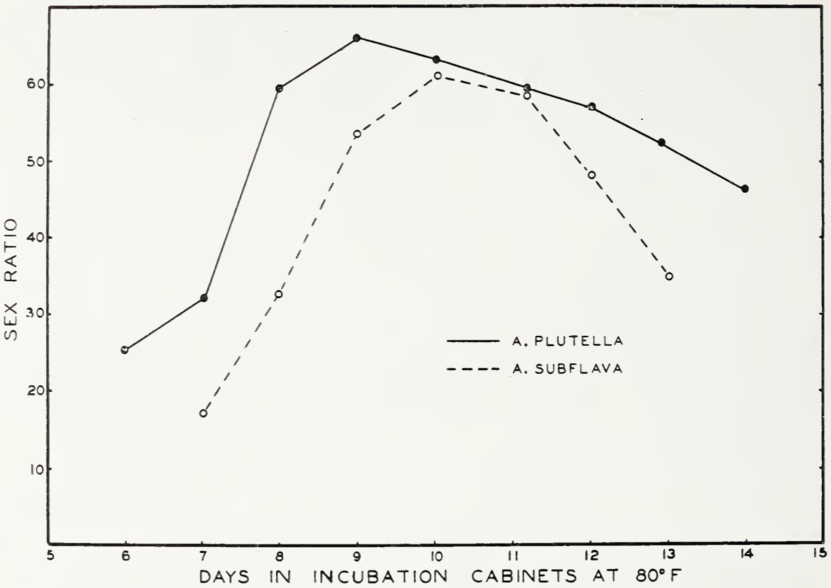

FIGURE 7.—Sex ratios (percent females) of *Aphelinoidea plutella* and *Abbella subflava* in beet leafhopper eggs as determined by rearings made in the incubation cabinets at 80° F. Twin Falls, Idaho.

Synchronization of Parasite and Host

A favorable synchronization of an egg parasite with its host is one in which the greatest number of parasites are present when the maximum number of host eggs are available for parasitization. It is assumed that the parasites would emerge in approximately the same locality that the host eggs were deposited.

In Russian-thistle areas in southern Idaho the spring emergence of *plutella* and *subflava* appeared to be favorably synchronized with the spring egg populations of the beet leafhopper as far as timing is concerned. At Berger in 1935, oviposition of the beet leafhoppers was almost completed by May 15, for on this date practically all the overwintering females were dead. Hatching of the first eggs of this generation, as determined by the length of time required for incubation in the cabinets and by the appearance of first-instar nymphs in the field, occurred approximately on May 17. By this time 67 percent of the overwintering *plutella* and 50 percent of the *subflava* had emerged from the dry Russian-thistle in the cabinets. Thus, all the eggs of the beet leafhopper that had been deposited in the spring host plants at this particular point had been exposed to at least 50 percent of the emerging parasites.

The favorable time synchronization of the parasites in the Russian-thistle areas was of little practical importance, however, as comparatively few overwintering beet leafhoppers remained in these immediate areas until the parasite emerged the following spring. Although the leafhopper developed enormous populations in Russian-thistle during the summer, chiefly on abandoned land as shown by Haegele (*4*), Carter (*2*), and Annand and others (*1*), most of the overwintering generation moved to surrounding areas during the fall when the summer host plants began to dry up. The parasites, which also produced enormous populations on Russian-thistle, were left behind within the dry plant tissues, except for those that were carried to the surrounding areas in blowing thistle plants. In the fall, as shown by Carter (*2*), Piemeisel and Chamberlin (*6*), and Fox (*3*), some of the leafhoppers moved to the sagebrush areas, where there were overwintering annuals such as green tansymustard. When germination of the overwintering and spring plants was delayed, few green plants were available as food and many leafhoppers survived for some time on sagebrush foliage. Other leafhoppers moved to abandoned areas, where flixweed (*Descurainia sophia* (Lam.) (Webb)), perfoliate pepperweed (*Lepidium perfoliatum* L.), and tumblemustard (*Sisymbrium altissimum* L.) were growing. When the plant succession was in the transition stage, with Russian-thistle as the summer annual and mustards the winter annuals, leafhoppers could be found in such locations throughout the year. However, the important spring-generation leafhoppers that moved into the cultivated and summer-breeding areas during the spring migration were developed in warmer environments somewhat distant from the local Russian-thistle areas, and this movement occurred after emergence of the two species of egg parasites had been completed (table 3). Thus it would appear that the beet leafhopper and the two egg parasites had an unsatisfactory space synchronization. With comparatively few eggs of the overwintering generation of beet leafhoppers available for parasitization in the Russian-thistle areas during the spring, the enormous populations of egg parasites surviving the winter in such environments were largely wasted.

Within recent years the breeding area of the beet leafhopper in southern Idaho has been changed, so that today most of the Russian-thistle is apparently growing on overgrazed rangeland. This environmental change should be advantageous to the egg parasites, as the poor space synchronization previously discussed should thus be largely overcome. The extent to which the Russian-thistle and spring mustard areas now overlap will determine how important this new situation might be with regard to the success of egg parasites in reducing spring populations of the beet leafhopper.

Summary

Studies were conducted in southern Idaho from 1932 through 1937 to determine the importance of *Aphelinoidea plutella* Gir. and *Abbella subflava* Gir. in parasitizing the spring brood of eggs deposited by the overwintering generation of the beet leafhopper (*Circulifer tenellus* (Baker)). The overwintering and spring emergence of these parasites were determined from samples of host-plant material collected at intervals and placed in especially constructed cabinets held at a constant light and temperature of 80° F.

Most of the first brood of both parasites and some of the second, third, and fourth broods emerged during the season of development.

The remainder of each brood entered a diapause and did not emerge until the following spring.

It was determined that the diapause was broken, presumably late in the fall, by low temperatures. After the breaking of the rest period, 6 or 7 days in the incubation cabinets were required for the initial emergence of parasites, and 50 percent emerged in approximately 8½ days. When emergence in the cabinets began during the first 24-hour period and 50 percent of the parasites emerged in 4 days, emergence was assumed to have begun in the field.

Of the parasites reared in the incubation cabinets 52 percent of *subflava* and 63 percent of *plutella* were females.

When the period of spring emergence of the two parasites was compared with the oviposition period of the overwintering beet leafhoppers in the Berger-Twin Falls area, it was found that the two were fairly well synchronized. However, most of the overwintering leafhoppers left the Russian-thistle when the plants began to dry in the fall. The spring-generation leafhoppers found in the beet fields of southern Idaho at the time of the spring movement had developed in warmer areas somewhat removed from the summer-breeding areas. At the time of this movement, the emergence of the two species of egg parasites had been completed. Thus, few eggs of the overwintering generation of the leafhoppers were present in the Russian-thistle areas for parasitization in the spring, and the enormous populations of egg parasites developing in such environments were largely wasted.

In recent years most of the Russian-thistle has been found on overgrazed rangeland along with the annual mustards. This situation should have a tendency to overcome the poor space-synchronization of parasite and host in the spring, and may thus increase the efficiency of the two egg parasites in controlling the beet leafhopper.

LITERATURE CITED

(1) Annand, P. N., Chamberlin, J. C., Henderson, C. F., and Waters, H. A.
1932. MOVEMENTS OF THE BEET LEAFHOPPER IN 1930 IN SOUTHERN IDAHO. U. S. Dept. Agr. Cir. 244, 24 pp.

(2) Carter, Walter
1930. ECOLOGICAL STUDIES OF THE BEET LEAFHOPPER. U. S. Dept. Agr. Tech. Bul. 206, 115 pp.

(3) Fox, D. E.
1938. OCCURRENCE OF THE BEET LEAFHOPPER AND ASSOCIATED INSECTS ON SECONDARY PLANT SUCCESSIONS IN SOUTHERN IDAHO. U. S. Dept. Agr. Tech. Bul. 607, 44 pp.

(4) Haegele, Rowland W.
1927. THE BEET LEAFHOPPER (EUTETTIX TENELLUS (BAKER)). A SURVEY IN IDAHO. Idaho Agr. Expt. Sta. Bul. 156, 28 pp.

(5) Henderson, Chas. F.
1941. APPARATUS AND TECHNIQUE FOR THE STUDY OF THE EGG PARASITES OF THE BEET LEAFHOPPER. U. S. Dept. Agr. Cir. 593, 12 pp.

(6) Piemeisel, R. L., and Chamberlin, J. C.
1936. LAND-IMPROVEMENT MEASURES IN RELATION TO A POSSIBLE CONTROL OF THE BEET LEAFHOPPER AND CURLY TOP. U. S. Dept. Agr. Cir. 416, 24 pp.

U. S. GOVERNMENT PRINTING OFFICE: 1955